The impact of information and communications technology infrastructure on economic growth: Does the financial system play an important role?

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Abstract: The study analyzes the impact of information and communications technology (ICT) infrastructure on economic growth in the 10 ASEAN countries. Furthermore, the study examines the role of the financial system in this impact, which is a novelty compared to previous research. To achieve this objective, the authors utilized Bayesian methods in estimating the research model. This method shows its superiority in elucidating the impact of variables in the research model and determining the probability of these impacts occurring. The results show that ICT infrastructure positively impacts economic growth in the ASEAN countries, with a 100 percent probability of occurring. Particularly, the financial system does not only directly affect economic growth but also plays an important role in enhancing the impact of ICT infrastructure on economic growth, with a probability of 98.24%. This is an interesting finding of the study. Additionally, economic growth is significantly influenced by the control variables, which are specifically government expenditure and inflation. The findings provide a reliable foundation for the ASEAN countries to identify appropriate solutions to improve the efficiency in managing ICT infrastructure, thereby advancing economic growth.

Keywords: ASEAN, Bayesian, Economic growth, Financial system, Managing ICT infrastructure.

1. Introduction

Nowadays, information and communications technology (ICT) has a close relationship with the process of economic growth (Bakry et al., 2023; Kallal et al., 2021; Kurniawati, 2022; Maneejuk & Yamaka, 2020; Saba et al., 2023), especially in the context of intensive globalization occurring in different countries (Farhadi et al., 2012). Indeed, ICT is a crucial component of modern technological infrastructure, with numerous applications widely used around the world (Ganda, 2024; Nguea, 2023; Niebel, 2018; Pradhan et al., 2015; Salimifar & Behname, 2013). ICT can drive the development of new technologies, reduce costs, increase innovation, and significantly contribute to restructuring the economy (Asongu, 2018; Asongu & Roux, 2017; Grimes et al., 2012; Lee & Brahmasrene, 2014; Lee et al., 2012; Penard et al., 2012). Furthermore, ICT serves as an effective bridge between businesses, customers, suppliers, and partners. Moreover, ICT facilitates rapid and easy information exchange, overcoming geographical barriers (Pradhan et al., 2015).

In fact, countless contemporary theories of economic growth have acknowledged the importance of ICT. Particularly, the theory of endogenous growth has emphasized the role of technology in economic growth. This theory has motivated many countries to innovate technologically to promote their economic growth. In recent years, technological advancements, particularly in ICT, have experienced remarkable development worldwide. Many countries have acknowledged the positive impact of ICT on economic growth, especially developed ones (Appiah-Otoo & Song, 2021; Dimelis & Pappainou, 2010; Haldar et al., 2023; Jung et al., 2013). For developing countries, investment in ICT remains low, and

supportive policies for such investment are limited, resulting in relatively low economic benefits from ICT (Dimelis & Pappainnou, 2010; Chavula, 2013). However, that ICT is well managed and adequately invested can significantly contribute to positive economic growth impacts in developing countries (Appiah-Otoo & Song, 2021). ICT is one of the vital indicators of technological development in each country. The positive impact of ICT on economic growth has been recognized in the current literature. In specific, ICT can bring many benefits to individuals, leading to an increase in per capita income, promoting savings and investment, and thereby driving economic growth (ÇalÕúkan, 2015; Asongu & Odhiambo, 2020). From a business perspective, ICT can help enterprises reduce costs, and enhance productivity, and competitiveness (ÇalÕúkan, 2015). At the national level, ICT contributes to enhancing a country's production capacity (Hong, 2016), linking each country's production activities with the global value chain, and increasing national competitiveness (Sassi & Goaied, 2013). Indeed, ICT also creates significant differences in economic growth performance among countries (Dimelis & Pappainou, 2010). For example, investment in ICT has helped the United States achieve higher economic growth performance than the EU in the late 1990s (Albiman & Sulong, 2016).

However, ICT does not always lead to economic growth (Pradhan et al., 2015). This is because the economic growth process can be influenced by the specific characteristics of each country (Nguyen, 2022). ICT can only play a stimulating role in economic growth when being managed and used efficiently, combined with favorable domestic conditions. To clarify this viewpoint, Pradhan et al. (2015) demonstrate that ICT and the financial system play important roles in promoting economic growth in Asian countries. However, the specific role of the financial system in the relationship between ICT and economic growth remains unclear in this study, which is still a question unsatisfactorily answered in the existing literature. Admittedly, by filling this gap, countries will have a basis to improve the efficiency of ICT, advancing sustainable economic growth. With this practical aim, this research is conducted to analyze the impact of ICT on economic growth in the ASEAN countries, considering the moderating role of the financial system in this impact. Consequently, the findings are not only expected to provide many interesting findings compared to previous studies but also to generate meaningful empirical evidence for the ASEAN countries. The rest of the study is organized as follows: section 2 provides an overview of the literature; section 3 outlines the methodology and data; the next section presents the results and discussion; and the final part concludes the study.

2. Literature Review

Theoretically, ICT is considered an important external factor that impacts economic growth, which is primarily explained through economic growth theories (Fernández-Portillo et al., 2020; Pradhan et al., 2015). In fact, ICT can create favorable conditions for business operations (Issahaku et al., 2018; Gosavi, 2018), contribute to expanding international trade (Maryam & Jehan, 2018), and thereby promote economic growth (Vu, 2019). In addition, ICT brings many benefits to people through easier access to services, increased savings, and investment opportunities (ÇalÕúkan, 2015; Asongu & Odhiambo, 2020). Therefore, the positive impact of ICT on economic growth has been affirmed in a large number of the existing literature, such as Jorgenson and Vu (2005), Dimelis and Papaioannou (2010), Vu (2011), Zuhdi et al. (2012), Sassi and Goaied (2013), Ward and Zheng (2016), Asongu and Odhiambo (2020), Awad and Albaity (2022). Moreover, some other studies have provided more specific insights into this impact. For instance, Yousefi (2011) contends that technology has a positive effect on economic growth, which is notably pronounced in developed countries. Kumar et al. (2015) report a positive impact of technology on economic growth in the Fiji Islands. However, to promote robust economic growth, technology investment should be diversified across various sectors rather than concentrated in only a few. Kumar and Stauvermann (2016) argue that mobile technology stimulates economic growth in both the short and long term. This study also recommends increasing investment in mobile technology in the fields of education, healthcare, and agriculture to enhance economic growth. Hussain et al. (2021) analyze the impact of technology penetration on economic growth in the four South Asian economies (India, Pakistan, Bangladesh, and Sri Lanka). The results

indicate that technology has a positive impact on their economic growth. Specifically, the level of internet penetration plays a more important role than mobile subscription penetration in economic growth. More recently, Nguyen and Doytch (2022) examine a dataset comprising 26 advanced economies and 17 emerging economies. The study reveals that technology patents significantly positively affect economic growth in advanced economies but exert a negative impact on it in emerging economies. Although the positive impact of ICT on economic growth has been found in most empirical studies, the extent of this impact depends on the specific characteristics of each country. Indeed, ICT can only stimulate economic growth when being managed and utilized effectively. In this regard, the study by Pradhan et al. (2015) examine the impact of ICT and financial systems on economic growth in Asian countries. The findings demonstrate that ICT and financial systems play an essential role in promoting economic growth in Asian countries, both in the short and long term. However, this study is limited in clarifying the role of financial systems in the relationship between ICT and economic growth. It is evident that the positive impact of ICT on economic growth has been affirmed in economic growth theories and most existing literature, but there is a notable absence of empirical studies examining the moderating role of financial systems in this impact, highlighting a significant gap that needs to be explored.

3. Methodology and Data

Some researchers have demonstrated that ICT can significantly impact economic growth (Asongu & Odhiambo, 2020; Awad & Albaity, 2022; ÇalÕúkan, 2015; Dimelis & Papaioannou, 2010; Jorgenson & Vu, 2005; Hussain et al., 2021; Kumar et al., 2015; Kumar & Stauvermann, 2016; Nguyen & Doytch, 2022; Sassi & Goaied, 2013; Vu, 2011; Ward & Zheng, 2016; Yousefi, 2011; Zuhdi et al., 2012). Furthermore, this impact may depend on the level of the financial system's development, focusing on financial markets and institutions (Pradhan et al., 2015). Based on this foundation, the authors suggest a research model with the equation as follows:

$$Y_{it} = \beta_0 + \beta_1 ICT_{it} + \beta_2 FS_{it} + \beta_3 ICT_{it} \times FS_{it} + \beta_4 GE_{it} + \beta_5 INF_{it} + \varepsilon_{it} \qquad (1)$$

Where: economic growth (Y) is determined using the logarithm of GDP per capita, which is consistent with the previous measures of Albiman and Sulong (2016), Asongu and Odhiambo (2020). ICT is defined using principal component analysis (PCA), formed on three component indices: fixed telephone subscriptions (% of population), mobile cellular subscriptions (% of population), and individuals using the Internet (% of population). The financial system (FS) is a composite index representing the development of the financial system, based on the development of financial markets and institutions (Pradhan et al., 2015). Additionally, the authors introduce an interaction variable ICT×FS to clarify the role of the financial system in the impact of ICT on economic growth, following the conceptual framework of Pradhan et al. (2015). The measurement of the ICT variable through PCA is described in Table 1.

Table 1.
ICT measurement.

Component	Proportion (%)
Fixed telephone subscriptions (% of population)	24.99%
Mobile cellular subscriptions (% of population)	33.28%
Individuals using the Internet (% of population)	41.73%
Total	100%

In addition, the authors include control variables in model 1, which consist of government expenditure as a percentage of GDP (GE) and inflation (INF). These control variables are identified following the framework of Asongu and Odhiambo (2020). For the data, the sample includes 10 ASEAN countries (Brunei Darussalam, Indonesia, Cambodia, Lao PDR, Myanmar, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) during the period 2000-2021. The financial system (FS) data are

obtained from the financial development database of the International Monetary Fund (IMF). The other variables are collected from the World Development Indicator (WDI) database of the World Bank.

For the estimation method, the authors use Bayesian method to estimate model 1. This is a relatively new approach aimed at explaining how ICT affects economic growth, particularly in highlighting the probability of this impact occurring and enhancing the robustness of the research findings (McNeish, 2016; Nguyen et al., 2022).

4. Empirical Analysis

The data sample was collected from 10 ASEAN countries during the period 2000-2021. Their descriptive statistics are presented in Table 2.

Table 2.
Descriptive statistics.

Variable	Mean	Std. dev.	Min.	Max.
Y	8.0817	1.5248	4.8788	11.2607
ICT	44.3936	29.7750	0.16	96.51
FS	0.3725	0.2228	0.03	0.83
GE	11.9963	5.3016	3.46	29.40
INF	4.4918	6.5530	-2.31	57.07

Table 2 shows that the average value of Y is 8.0817 (equivalent to $9,915.49), with the lowest value (4.8788, corresponding to $131.47) observed in Myanmar in 2002, and the highest value (11.2607, corresponding to $77,710.07) observed in Singapore in 2021. For ICT, the average value is 44.39%, with the lowest value observed in Myanmar in 2000 (0.16%) and the highest value observed in Singapore in 2019 (96.51%).
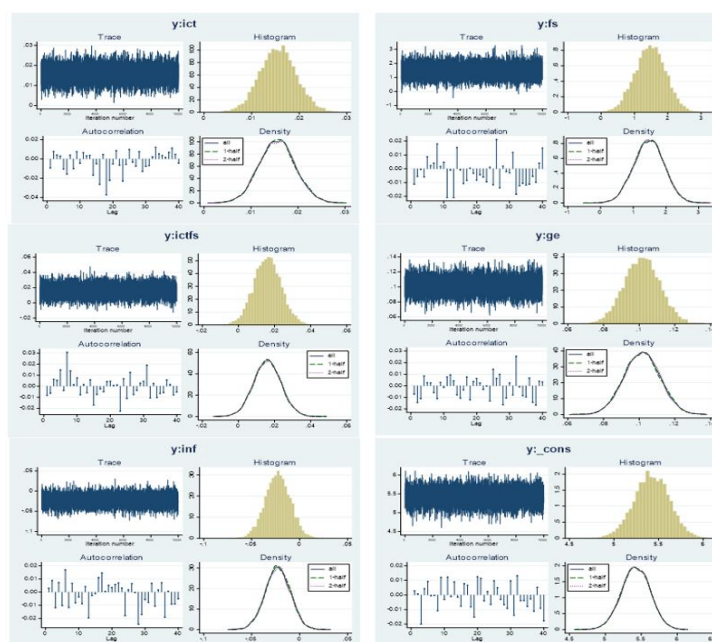
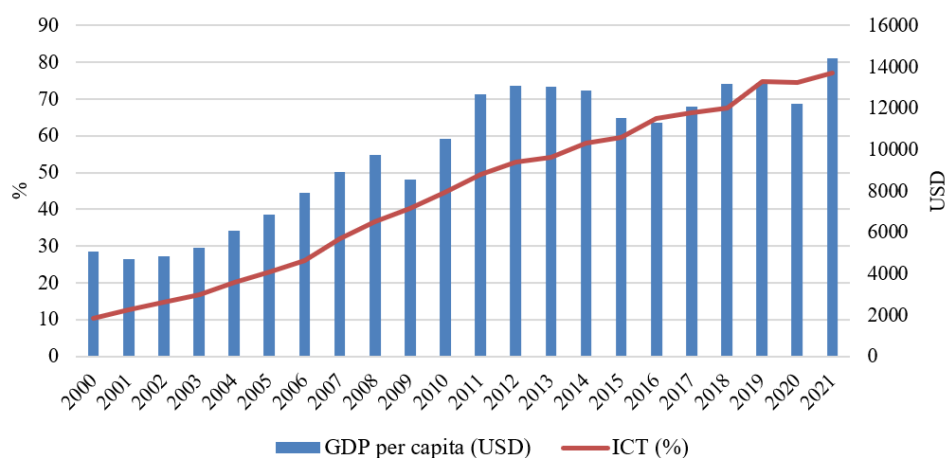**Figure 1.**
Convergence diagnostics.
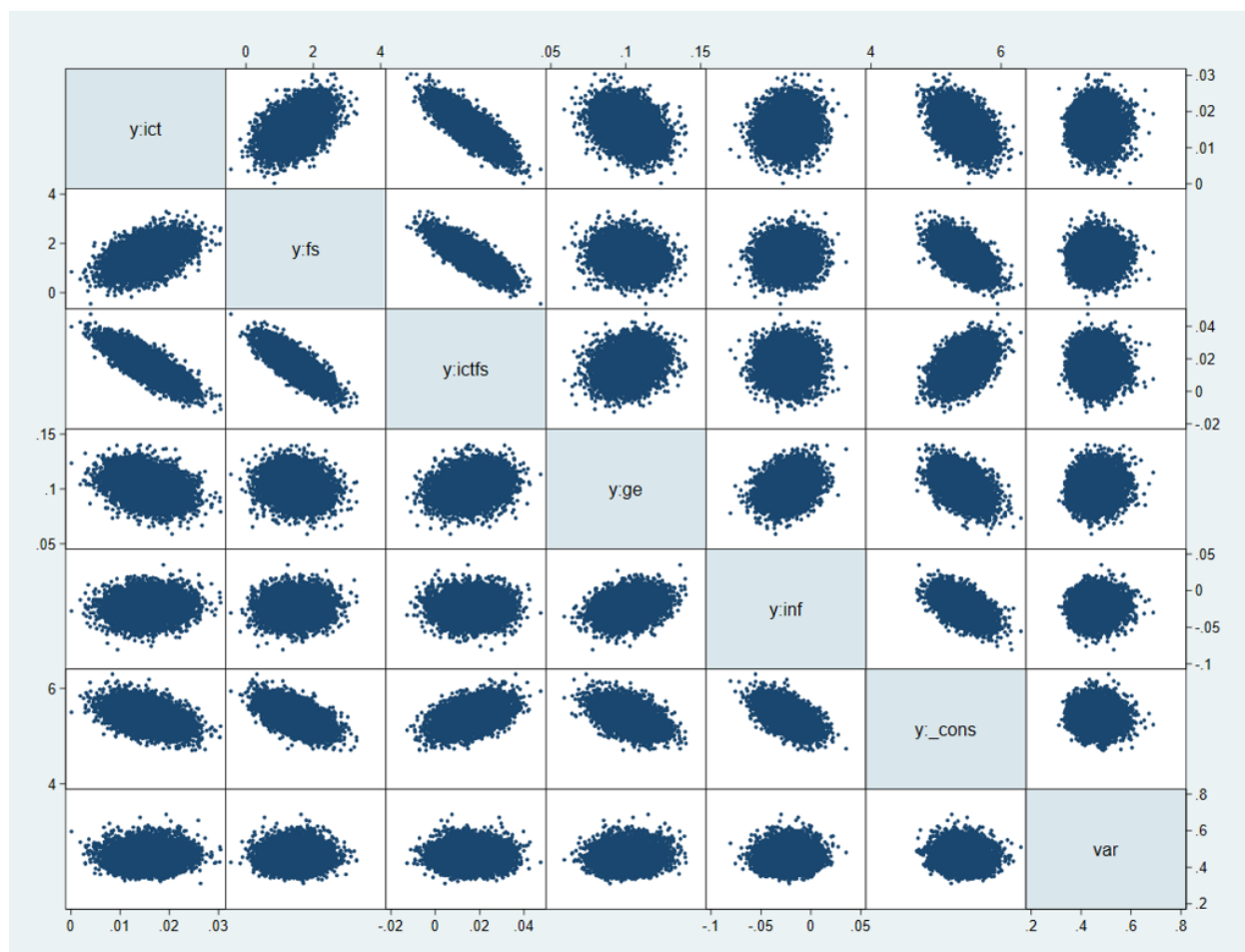
Figure 2.
Bayesgraph matrix.

Figure 1 and Figure 2 demonstrate that the variables in Model 1 meet the convergence criteria and are usable. Specifically, the Trace Plot is relatively smooth, the Autocorrelation plot shows relatively low autocorrelation concentrated mainly below 0.02, and the Histogram and Density plots resemble the shape of a standard distribution.

Table 3.
Correlation matrix.

Variable	Y	ICT	FS	ICT×FS	GE	INF
Y	1.0000					
ICT	0.7805	1.0000				
FS	0.6938	0.6313	1.0000			
ICT×FS	0.7747	0.8572	0.8778	1.0000		
GE	0.5453	0.3224	0.1443	0.1781	1.0000	
INF	−0.4798	−0.3741	−0.3431	−0.3589	−0.3599	1.0000

To better understand the relationships between the variables, the correlation is examined with the results shown in Table 3. As can be seen, inflation (INF) is negatively correlated to Y, while the relationships between the other variables and Y are positive (Figure 3).

Figure 3.
GDP per capita and ICT of the ASEAN countries.

Next, the authors use Bayesian method to analyze the impact of ICT on economic growth in the ASEAN countries. With this approach, the impact of ICT on economic growth is assessed in terms of the extent and probability of this impact occurring, which cannot be fully addressed by traditional estimations.

Table 4.
Results of estimating the model using the Bayesian method.

Y	Mean	Std. dev.	MCSE	Median	Equal-tailed [95% cred. interval]	
ICT	0.0156	0.0038	0.0000	0.0156	0.0081	0.0232
FS	1.4775	0.4644	0.0046	1.4761	0.5738	2.3946
ICT×FS	0.0161	0.0076	0.0001	0.0161	0.0012	0.0312
GE	0.1016	0.0100	0.0001	0.1017	0.0819	0.1211
INF	−0.0228	0.0130	0.0001	−0.0228	−0.0487	0.0022
_cons	5.4233	0.1992	0.0020	5.4241	5.0274	5.8070
Avg acceptance rate	1					
Avg efficiency: Min	0.9493					
Max Gelman-Rubin Rc	1					

Table 4 shows that the analysis results using Bayesian methods are appropriate. Specifically, the average acceptance rate, minimum effective sample size, and maximum Gelman-Rubin Rc are all satisfactory. Additionally, the Monte Carlo Standard Error (MCSE) of all parameters is very small (less than 1%), indicating that all the variables have a significant impact on economic growth. In specific, ICT has a positive impact on economic growth, which aligns with the findings of most previous researchers such as Jorgenson and Vu (2005), Dimelis and Papaioannou (2010), Vu (2011), Zuhdi et al. (2012), Sassi and Goaied (2013), ÇalÕúkan (2015), Yousefi (2011), Kumar et al. (2015), Kumar and Stauvermann (2016), Ward and Zheng (2016), Asongu and Odhiambo (2020), Hussain et al. (2021), Awad and Albaity (2022), Nguyen and Doytch (2022). Therefore, ICT is essential in promoting individuals to increase savings and investment, helping businesses reduce costs and enhance productivity. At the national level,

ICT contributes to boosting a country's production capacity, improving the linkage between its production activities within the global value chain, thereby promoting economic growth. Furthermore, this study also emphasizes the importance of the financial system (FS) in economic growth which is consistent with the earlier assertion by Pradhan et al. (2015). However, this study reports a positive impact of the interaction variable ICT×FS on economic growth. Therefore, the financial system does not only directly affect economic growth but also enhances the impact of ICT on it. This is a new finding of this study compared to previous research. Regarding the control variables, economic growth is positively affected by government expenditure (GE) and negatively affected by inflation (INF). This confirms what has been previously reported by Asongu and Odhiambo (2020).

Table 5.
Results of interval.

Interval tests	Mean	Std. dev.	MCSE
Prob: {Y:ICT} > 0	1	0	0
Prob: {Y:FS} > 0	0.9993	0.0265	0.0003
Prob: {Y:ICT×FS} > 0	0.9824	0.1315	0.0013
Prob: {Y:GE} > 0	1	0	0
Prob: {Y:INF} < 0	0.9630	0.1888	0.0019

The authors use interval tests to determine the probability of the relation between the variables and economic growth, with the results presented in Table 5. Accordingly, the probability of a positive impact of ICT on economic growth is 100%. The study also finds the significant role of the financial system in enhancing the impact of ICT on economic growth, with a probability of occurrence of 98.24%. This is an interesting finding of the study compared to previous research. Regarding the control variables, the probability of these variables impacting economic growth is also very high. This significantly contributes to affirming the suitability of the proposed research model in this study.

5. Conclusion

In this study, the authors examine the impact of ICT on economic growth in the ASEAN countries. Furthermore, they consider the role of the financial system in this impact, which is one of its novelties compared to previous research. By using Bayesian methods, the results show that ICT exerts a positive impact on economic growth with a probability of 100%. Additionally, the financial system positively impacts economic growth with a probability of 99.93%, and the interaction variable ICT×FS also positively affects economic growth with a probability of 98.24%. Thus, the financial system does not only directly affect economic growth but also enhances the impact of ICT on economic growth, which is a new finding of this study compared to previous research. For the control variables, economic growth is significantly affected by government expenditure (GE) and inflation (INF). Based on these findings, the ASEAN countries will have a reliable basis to formulate appropriate policies related to ICT management to promote economic growth. Specifically, they need to make further efforts to improve the quality and efficiency of managing ICT infrastructure. Policymakers should ensure the accessibility of modern technologies for consumers and businesses. Furthermore, they need to improve communication efforts so that citizens and businesses understand the importance, benefits, and potential risks of using ICT and other modern technologies. In addition, they can further develop towards privatization to attract foreign investors and enhance equitable competition in developing ICT infrastructure. Moreover, they should focus on improving domestic conditions, especially in the financial system, to create favorable conditions for enhancing the effectiveness of ICT in the economic growth process.

This study successfully achieves its objective of analyzing the impact of ICT on economic growth in the ASEAN countries and clarifying the role of the financial system in this relationship. However, the study still has certain limitations. For instance, the scale of the data sample used in this study is limited, especially in terms of the number of countries included. Furthermore, data limitations have prevented

the study from analyzing the research model for each individual country. These limitations suggest interesting directions for future research.

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